



Satellite Laser Communications on the Cheap

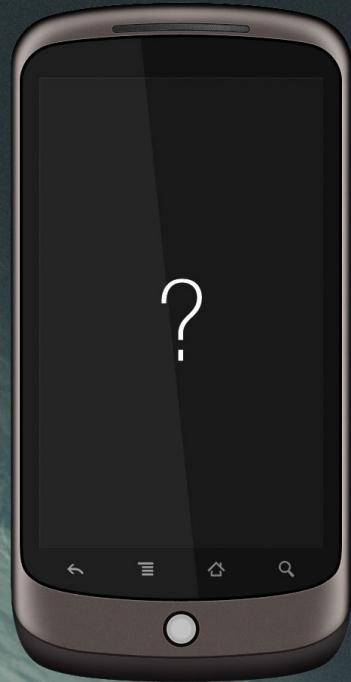
William Marshall
PhoneSat Project



Overview

1. PhoneSat
2. LightForce
3. Modulating Retro-reflectors for Laser Communications
4. PhoneSat + LightForce + MRR = cheap satellite laser coms?

P H O N E S A T



CAN WE TURN A PHONE IN TO A SATELLITE?



Why Phone Based Satellite?

Status quo:

- Typical satellite costs: \$500m
- 'Low Cost' satellites: \$10m

But...

- All key capabilities of a satellite are in a phone
- A cell phone based satellite costs ~\$5k in parts
- Launch for a 1U = \$50-70k

→ With a 100x reduction in cost, could there be a vast array of new potential applications?



Technology

	Satellite	SmartPhone
Computer system		
Processor	/	/
Memory	/	/
Power system		
Battery	/	X
Solar Arrays	X	
Structure		
Strong frame	/	
ADCS		
Accelerometers	/	
Rate Gyros	/	
Magnetometers	/	
Sun sensor	?	
GPS	/	
Reaction Wheels	X	
Magnetorquers	X	
Communications		
Radio	/	
Payload		
Camera	/	



Phone software overview

- Android 2.1 Operating System
- Help from several Googlers on their 20% time:
 - Image compression algorithm
 - Serial data port
- Open Source Project (HW and SW)

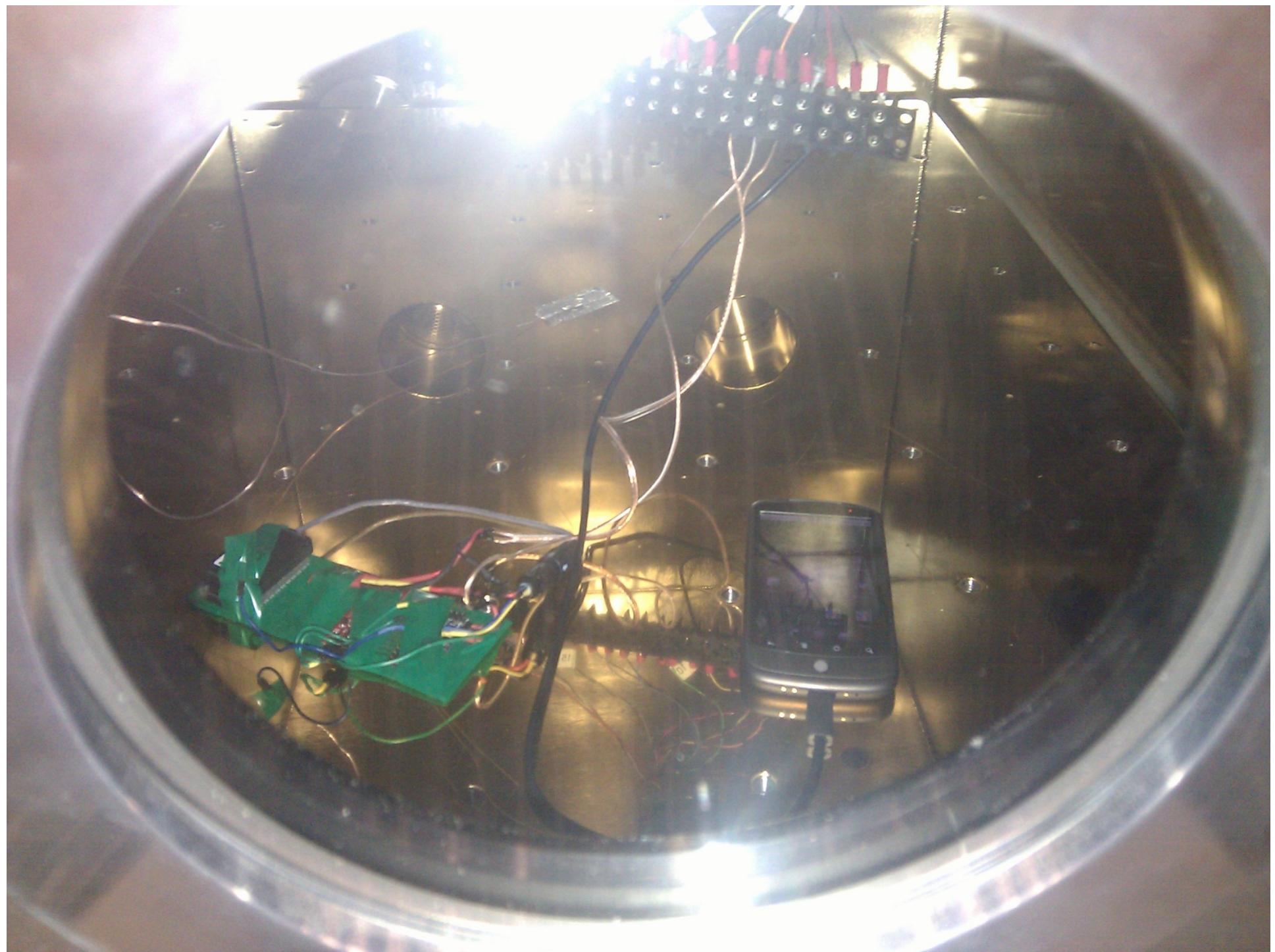


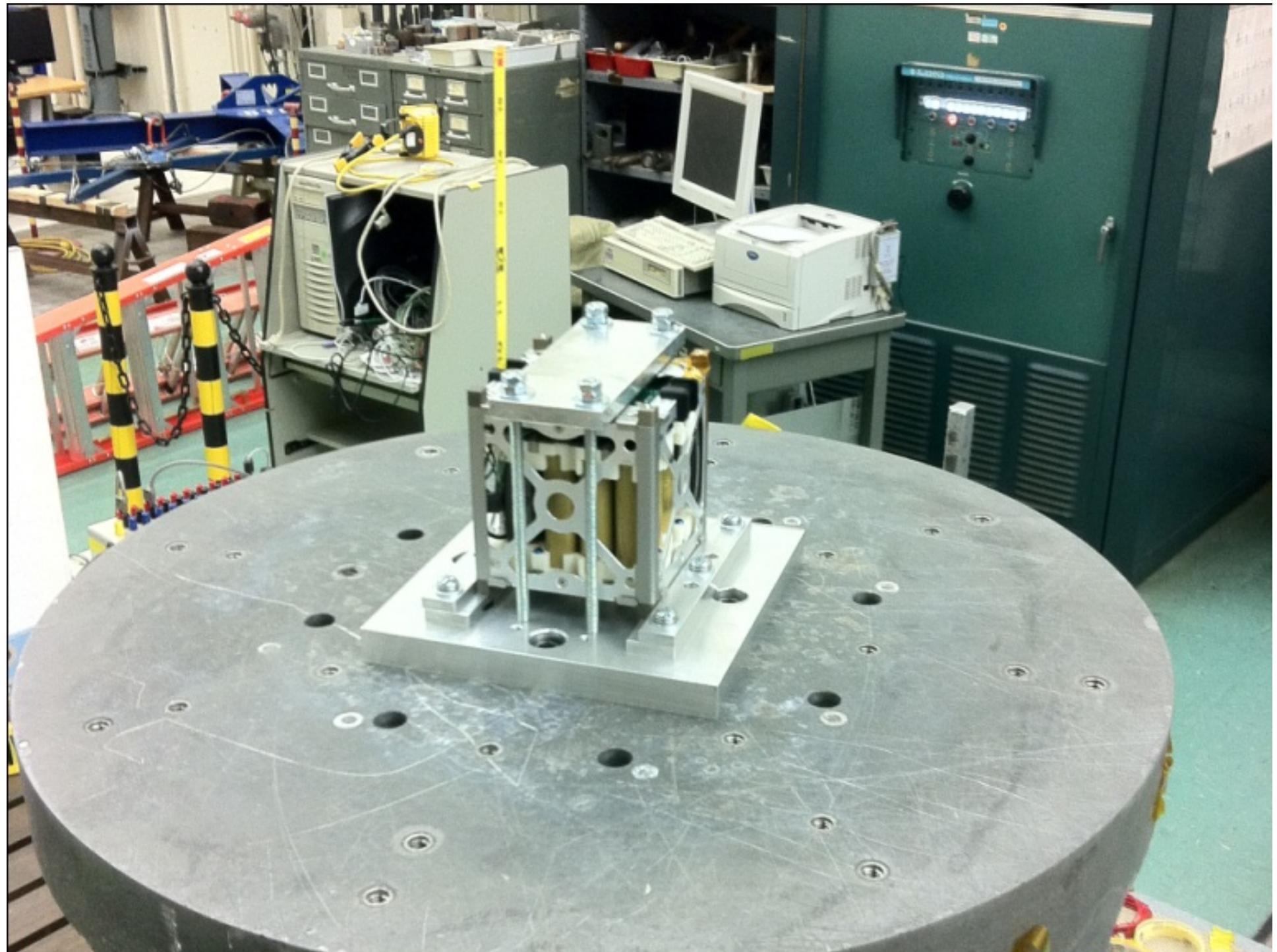


Space Qualification Testing

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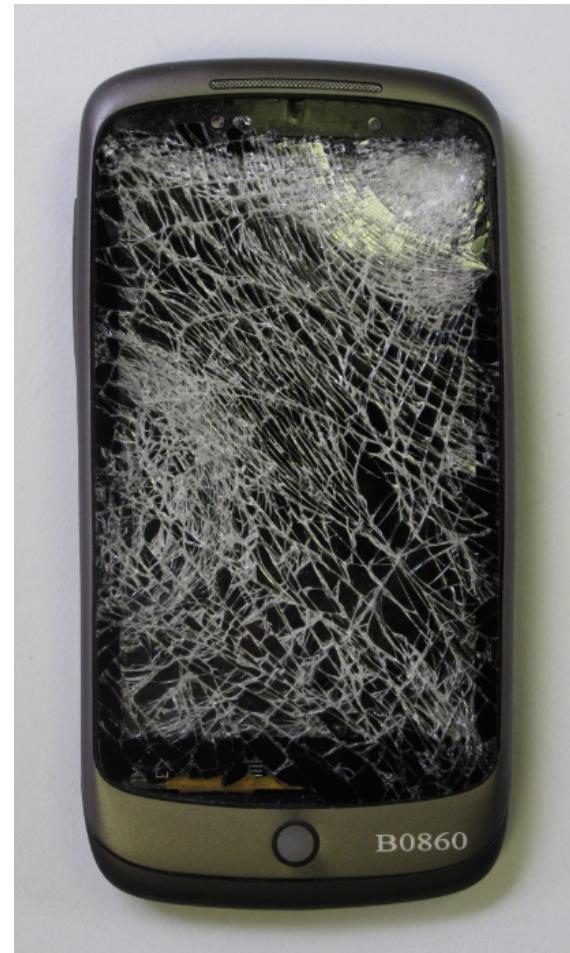








Launch 1: high altitude; fail



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Next Steps

Launch 3x PhoneSat 1.0 in June 2012

- Taurus II --> 280x280km orbit
- Duration 3 weeks
- Launch Cost: \$250k (for 3 satellites)

Launch 1x PhoneSat 2.0 in December 2012

- Falcon 9/Dragon --> 450x300km orbit
- Duration: 3-6 months
- Cost: free through ELaNa programme



And, what if sats cost \$10k?

Heliophysics

Missions to space test hardware

Swarmed satellites

Remote Sensing?

Personal Satellites?

...

Quantum Physics tests?

PhoneSat 1.0





LightForce

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Problem





Solution Space

1. Active Debris Removal

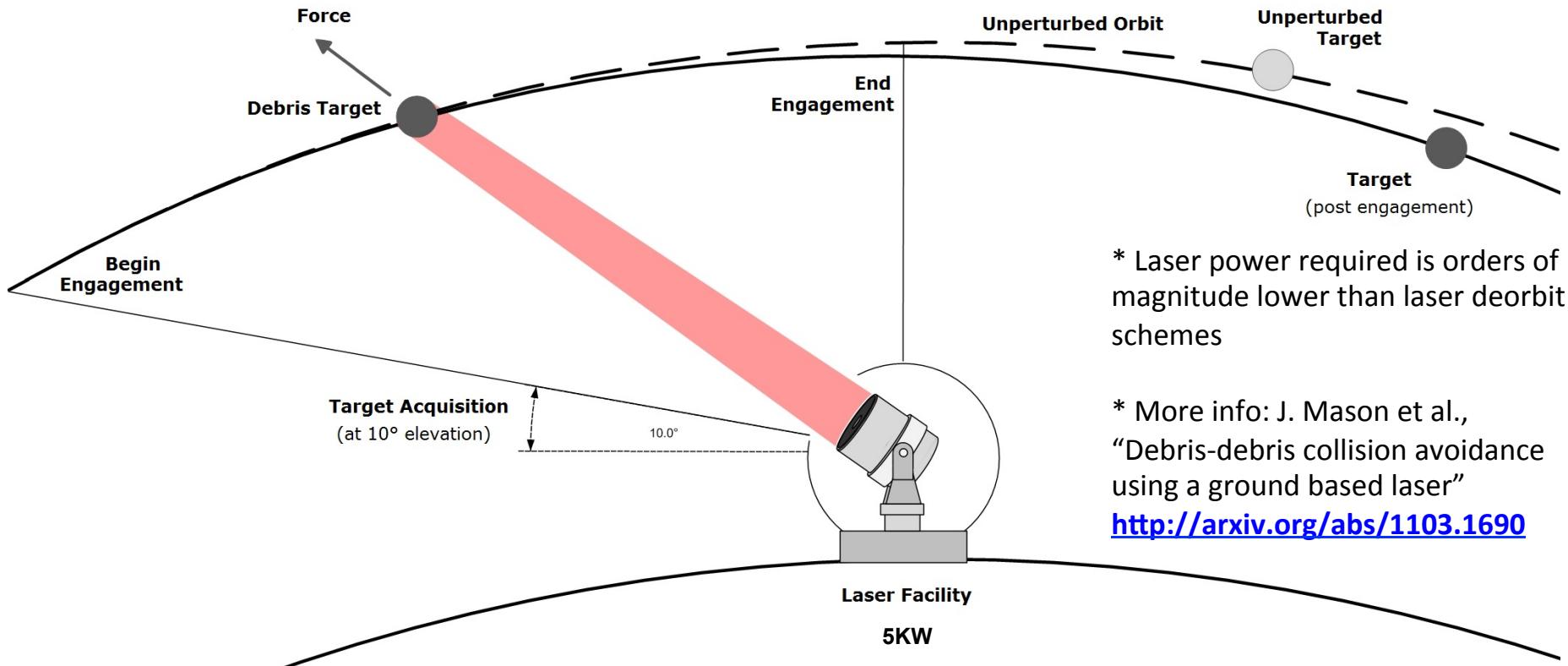
1. Satellite with grappling mechanism to capture debris → expensive!
2. Large laser to ablate debris → expensive and dangerous!

2. Preventing Collisions

1. Prevent Collisions involving a maneuverable Satellites → possible but insufficient
2. Prevent Collisions involving any object → how does one maneuver debris?



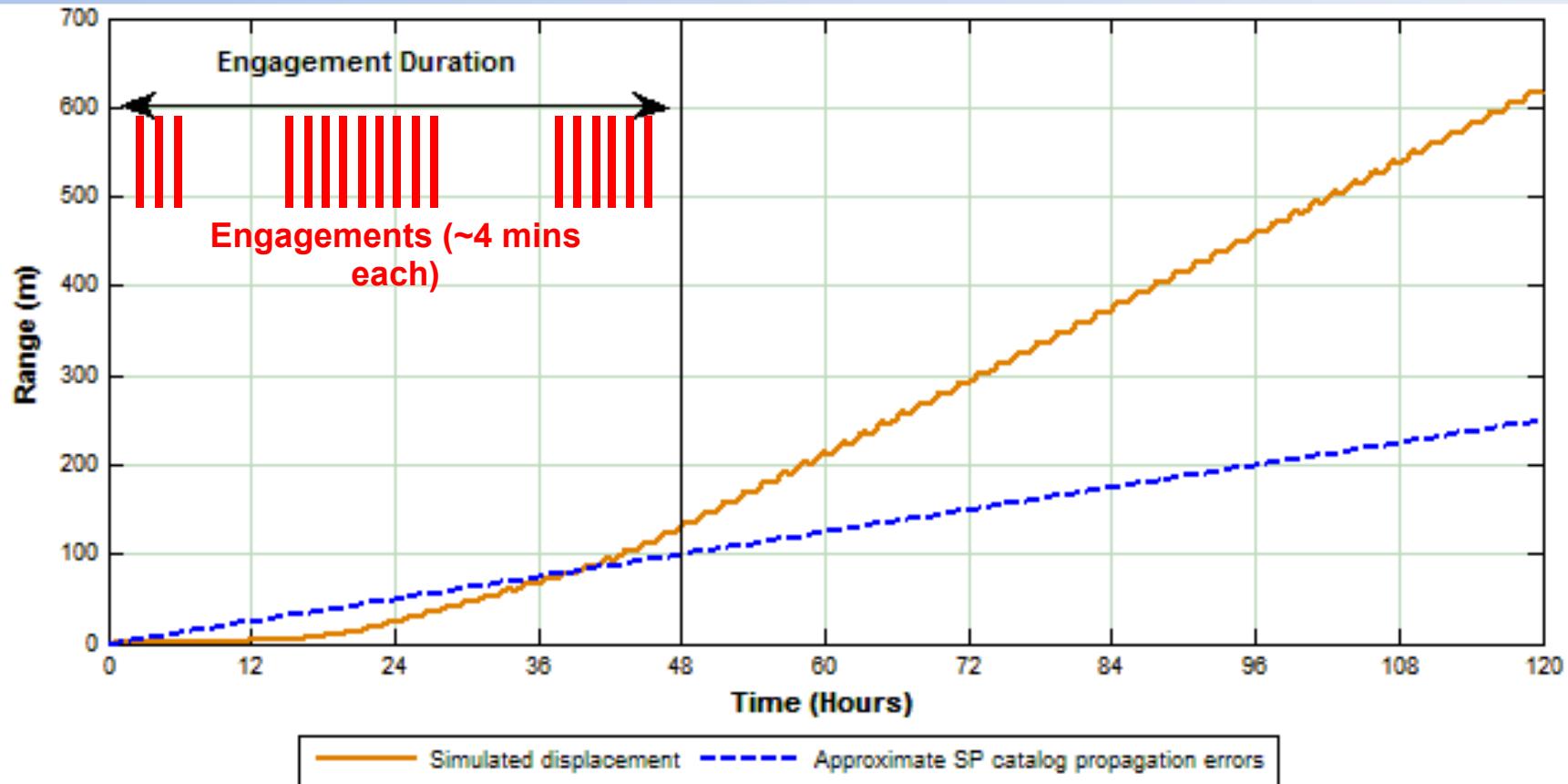
Concept: nudge debris



LightForce uses photon-pressure from medium power ground-based laser to nudge (~mm/s) debris to prevent collisions



Photon Pressure Sufficient



Simulated debris target engagement using 5kW CW laser near-polar laser facility (with AO) and 48 hours of engagements (18 passes). **Nudging exceeds prediction error.**



Modulating Retro-Reflectors

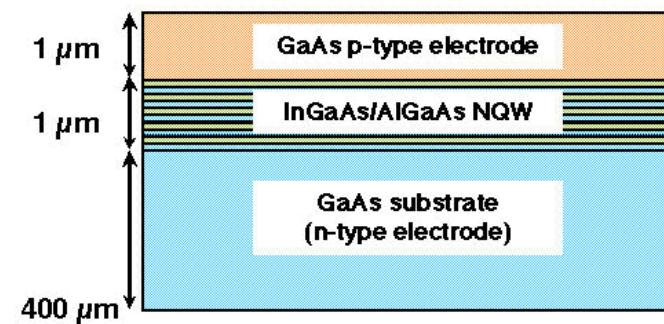
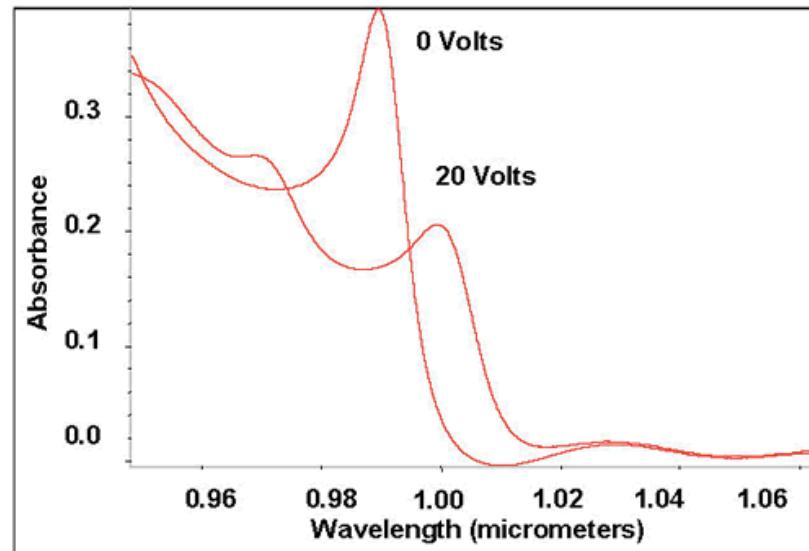
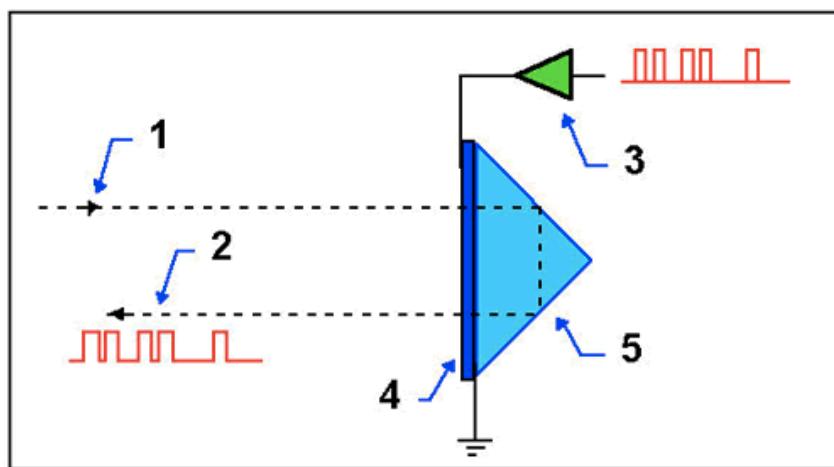
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Introduction to MRRs

Courtesy NRL: www.nrl.navy.mil/fpc0/mrr





Modulating Retro-reflectors

Not a new idea, nor our idea! – been under development at NRL and elsewhere for ~20 yrs:

[1] Concept: J. Fergason, Modulating Retroreflector System, US Patent 4983021 (1991)

[2] Demonstration: e.g. Rabinovich et al., 45-Mbit/s cat's-eye modulating retroreflectors, Optical Engineering 46-10-, 104001 October 2007

Application to Satellites

- Small satellites today use RF comms channels with
 - data rates (typically 10-100kbps)
 - power consumption ~5 W
- **MRR can provide**
 - Fast communications (10 Mbps – Gbps)
 - Low power consumptions (e.g. 0.1 W)
- **ANDE Mission**
 - In space demo proposed (but not flown) on ANDE mission

[3] A.C. Nicholas et al. The Atmospheric Neutral Density Experiment (ANDE) And Modulating Retroreflector In Space (MODRAS) V, Anton Kohnle, John D. Ginglewski, Editors, Proceedings of SPIE Vol. 4884 (2003) © 2003 SPIE

Catch: more complex ground station

- Need a 1kW laser through a 1m telescope to make the link budget work
- Need ~arcsec tracking

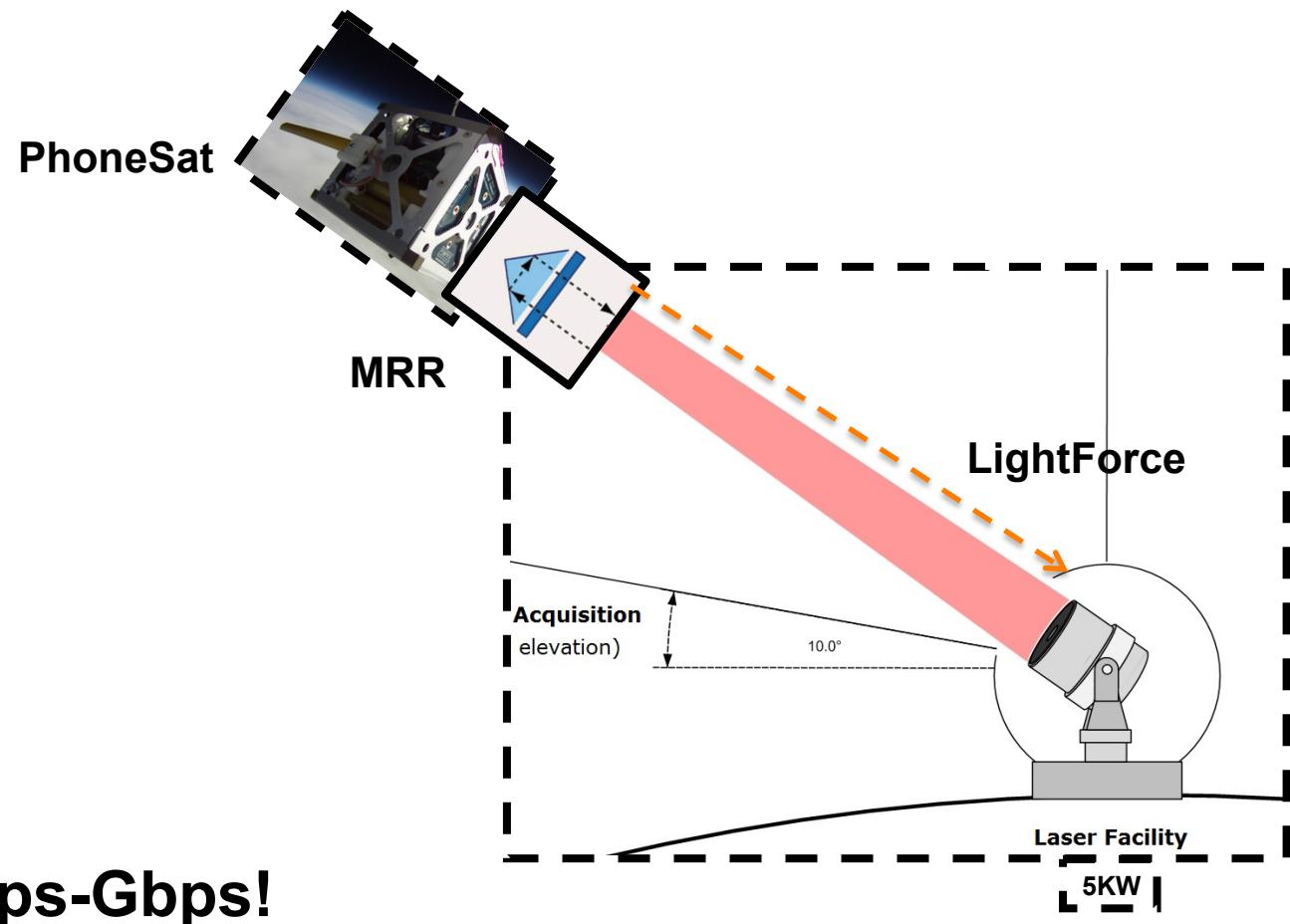


PhoneSat + MRRs + LightForce

**= cheap satellite laser
comms demo?**



PhoneSat + MRRs + LightForce



→ Mbps-Gbps!

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PhoneSat + MRRs + LightForce

Where is the project today?

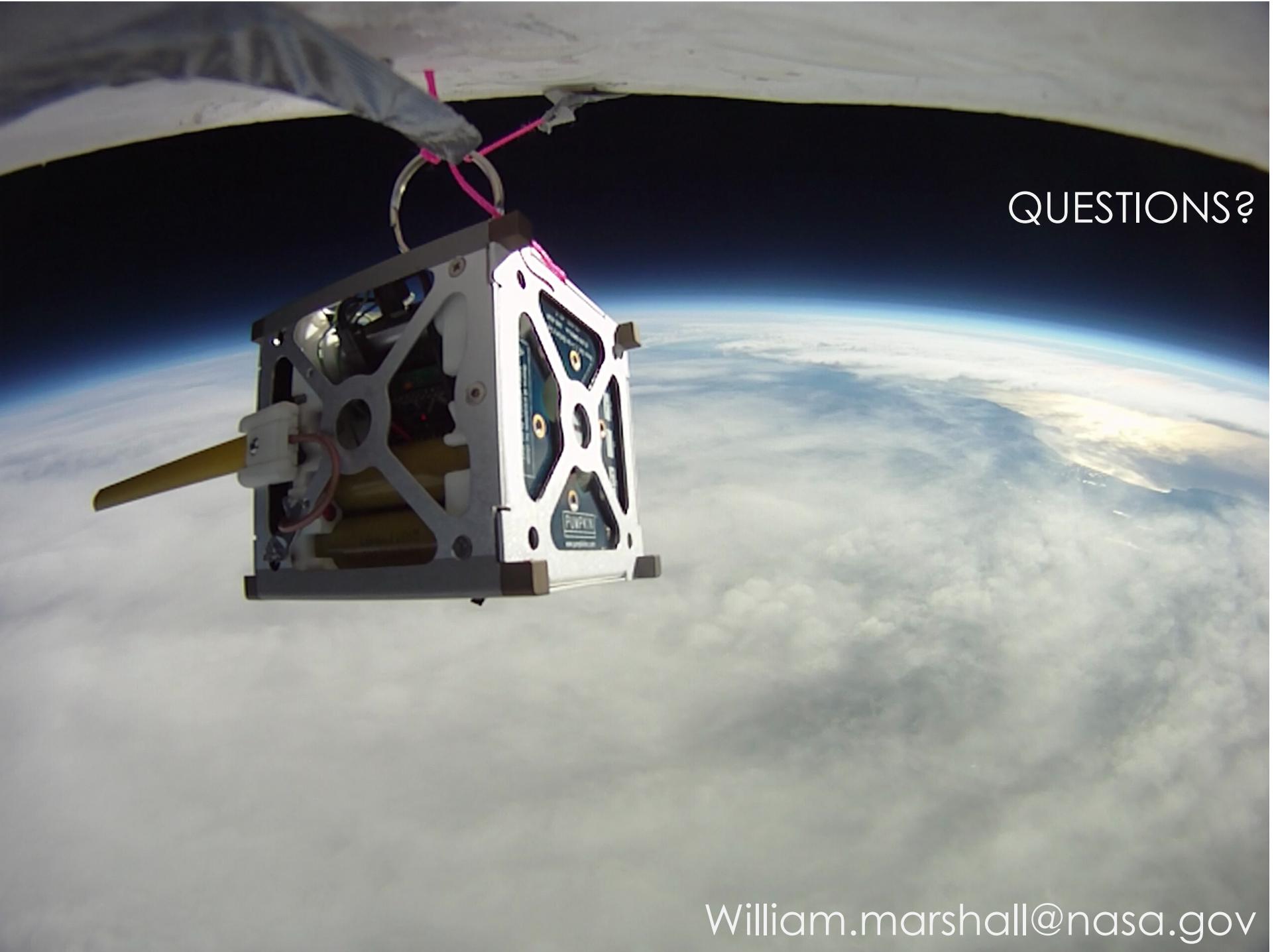
- MRR working in the lab (courtesy of NRL)
- PhoneSat 2.0 construction and testing underway
- Mt. Stromlo facility able to track satellites with retro-reflectors

Plan going forward

- Launch PhoneSat 1.0 → test link budget [June 2012]
- Develop MRR at 1um (NRL)
- Integrate MRR to PhoneSat 2.0
- Launch PhoneSat 2.0 to test space laser comms [**December 2012**]

Quantum Ideas and needs

- Idea: PhoneSat a cheap platform for Q. missions?
- Idea: MRR could perhaps test Q. communication protocols?
- Need: better Geiger mode APDs at 1um



QUESTIONS?

William_marshall@nasa.gov